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Integrated Global Nuclear Materials Management - Preliminary Concepts -

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NHI
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Context

- The generation, flow, and use of nuclear materials is essential to international security and is a fundamental compelling and enduring mission of DOE/NNSA
- Nuclear material activities and threats are "global" and continue to expand
- U.S. homeland security requires global nuclear materials management - globally integrated defense-in-depth
- An overarching concept is needed to address existing legacy nuclear/radiological materials and transition towards a nuclear energy future, while strengthening the global nonproliferation regime
- An consistent framework would help achieve an integrated and global view to help direct the USG technology development and complementary policy strategies

Systems Approach to Connect Global Objectives and Local Actions

- Articulate global objectives into a hierarchy of subsystem requirements and local attributes and measures
- Establish a baseline system and viable alternatives through the interactions and relationships (e.g., networks) of local system elements and their options
- Evaluate performance of system alternatives and develop improved nuclear material management strategies and technologies
- The need to address greatest concerns first (prioritized or graded approach) and to make tradeoffs among implementation options and competing objectives entails a risk-based approach

Particular interest in navigating the transition from nuclear material legacy -- through present-day -- to emerging nuclear future

Integrated Global Nuclear Materials Management (IGNMM)

- IGNMM could provide a systematic understanding of global nuclear materials management and evolutionarily improve and integrate the management through an active architecture, using for example, situation awareness, system models, methods, technologies, and international cooperation

- Different tools would be used within the overall framework to address individual issues on the desired geographic scale that could be easily linked to broader analyses

- Life-cycle system analyses would allow for evaluating material path alternatives on an integrated global scale

- Disconnects, overlaps, technical options, and alternatives for optimizing nuclear materials processes could be evaluated in an integrated manner

Manage the Risks

- **We need strategies to manage nuclear material network risks, for example:**
  - — If security is to be achieved through redundancy, the redundant devices should be diverse
  - — Diversity: identify sources of correlated faults, and utilize security elements not susceptible to those sources
  - — Decentralization and decoupling: protecting critical elements by isolating them may make them more vulnerable if their isolation can not be guaranteed
  - — It may pay to search for effective ways to reduce propagating events at the cost of other benefits or efficiencies (e.g., operations)
    - Institutional controls that act as ‘safety switches’
    - Build in more tolerance for lower risks to achieve less tolerance for higher risks (e.g., performance based regulatory and control regimes)

IGNMM Activities May Be Viewed as a Complex Network

- **Complex, decentralized networks are common: consist of nodes of activity with links among the nodes**
  - The Worldwide Web
  - Transport routes among US cities
  - Distribution supply to Wal-Mart
  - Global oil and steel enterprises
  - Source, movement, and use of nuclear materials

- **The research challenge is to anticipate where and how security failures can occur in a dynamic nuclear material network and how to prevent them**
  - Complexity entails that the usual system analysis approach of partitioning components can miss important behaviors: prior events can effect unexpected subsequent behavior (e.g., legacy materials and terrorism)
  - Uncertainty: there are too many scenarios to use that approach, so how do you manage system uncertainties?

Risks and Vulnerabilities

- **Need to understand the network system risks**
  - — Man-made networks exhibit distributions of performance fluctuations at nodes and along links
    - Implies likelihood and magnitude of variances in security may be predictable
    - Implies catastrophic events are inevitable; but likelihood can be reduced by design
  - — Highly interactive network elements can lead to large vulnerabilities and failures

- **Vulnerabilities in a network system**
  - — Independent events (e.g., site reactor operations)
  - — Correlated or common mode events (e.g., inherent vulnerabilities in similar process facilities or transportation modes)
  - — Propagating events (e.g., incremental diversion of materials or technology to bad actors)
  - — Attacks or deliberate failures: exploit some vulnerability in a surprising new way (e.g, clandestine program among more than one monitored state)

Some Key Issues

- **Defense-in-depth - address all phases of nuclear material-related risks**
  - Securing and safeguarding source material
  - Detection and tracking material movement and processes
  - Interdiction and response to undesirable events
  - Diversity in prevention and mitigation approaches and measures
  - Reducing attractiveness of fuel materials and process streams for weapons-usability

- **Test management strategies using systematic assessment of risks vs. investments**
  - Developing technical and institutional options to increase barriers to proliferation
  - Which technologies and systems should be deployed and where?
  - What new capabilities are needed to address challenges?
  - How can we work most effectively in international cooperation?

Proliferation Resistance of Emerging Generation of Nuclear Energy Fuel Cycles

- **Starting with a basis of nuclear materials inventory, movements and security, this framework can be used in evaluating proliferation resistance of possible fuel cycle options**
- **Established or evolving methodologies would be used to evaluate options (e.g., PR & PP)**
- **PR & PP evaluation measures include:**
  - Quantity, attractiveness, and accessibility of weapons-usable materials
  - Potential for delays in or detection of weapon production activity
- **Improved IGNMM performance requires constant iteration among situation awareness, assessment of the risk landscape, and developing better management strategies**

Examples of S&T thrusts and cross-cutting capabilities

- System and risk sciences for complex, decentralized networks
- Identification of diversion of nuclear material
  - Improving nuclear security
  - Nuclear latency management and the world's future nuclear control regime (e.g., up-to-date situational awareness of high-risk material inventory & location)
  - Quantify margins of uncertainty
  - Near-real-time warning and incident characterization
  - New material forms and technologies for surety of anticipated nuclear technology developments
- Bridging the knowledge gap between S&T and policy development and implementation

S&T capabilities to be applied

- Information acquisition, data management, simulation and modeling, and decision support
- System and risk sciences for complex, decentralized networks of activities
- Material forms, technologies, and behaviors for surety of anticipated nuclear technology developments
- Enhanced detection and monitoring technologies and practices
- International collaborations on nuclear management issues and control regimes
- Data integration and optimal user interface

Example Payoffs

- **Propagate best and improved material control programs and practices**
  - — Master material management plans
  - — Reduction and consolidation of material inventories
- **Transportation security under new governance regimes**
- **Optimized disposition paths and end-states**
- **Better understanding of latency management or proliferation plausibility**
- **More effective regional security measures and cooperation**
- **Support or effective future nuclear fuel cycle regimes**